Enhancing Surface Data Assimilation and Near-Surface Weather Forecasts in NGGPS through Improved Coupling between the Land Surface and Atmosphere

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NGGPS Principal Investigator's Meeting

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NCWCP, College Park, Maryland

Outline

Summary of the progress

- Evaluating near-surface weather forecast errors

- Understanding covariances between soil and atmospheric states
  - Observational analysis
  - A single column model study
  - A strongly coupled land-atmospheric system (e.g., WRF-Noah)

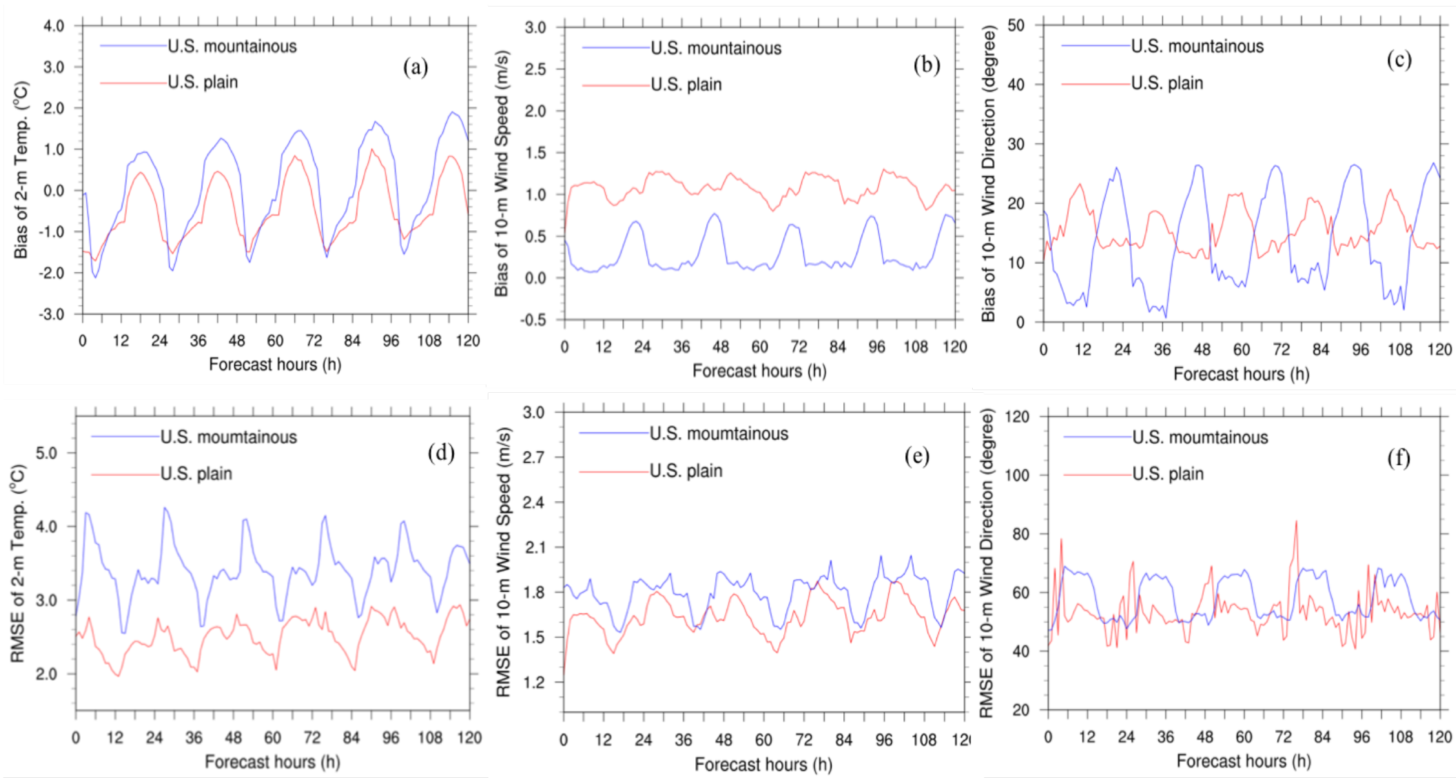
- Examining the influence of strong coupling on soil moisture data assimilation with SMAP satellite data

- On-going development
  - Strong coupling within the GSI framework
  - NGGPS (NCEP FV3) coupling with NASA LIS

Evaluating near-surface weather forecast errors

Mean bias and RMSE for 2-m temperature and 10-m winds

GFS. - U. S. Mountainous vs. U. S. Plains
00UTC FCST, June 2016

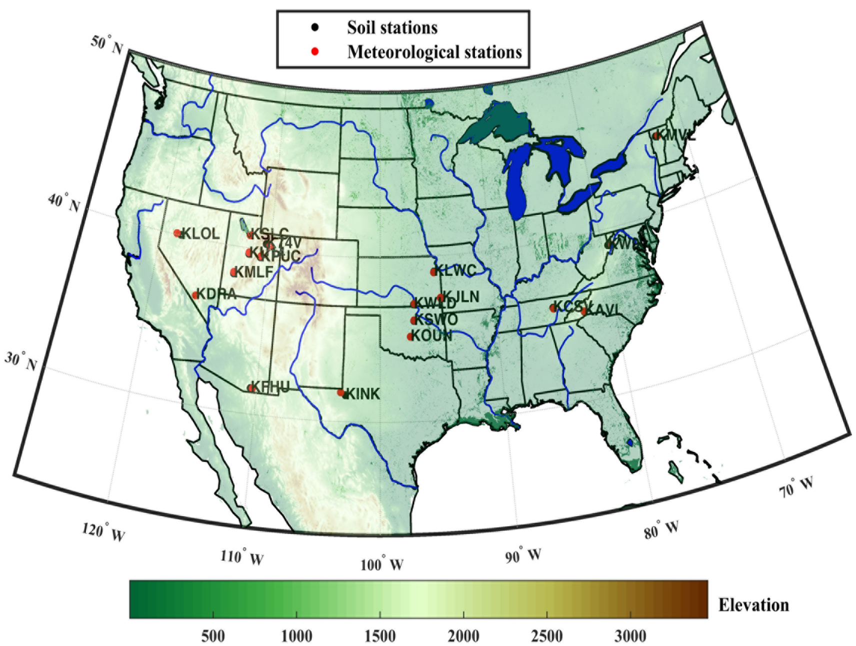


Understanding covariances between soil and atmospheric states

Observational analysis (Student J. Liu)

Is soil moisture a major factor that affects near-surface weather forecasts?

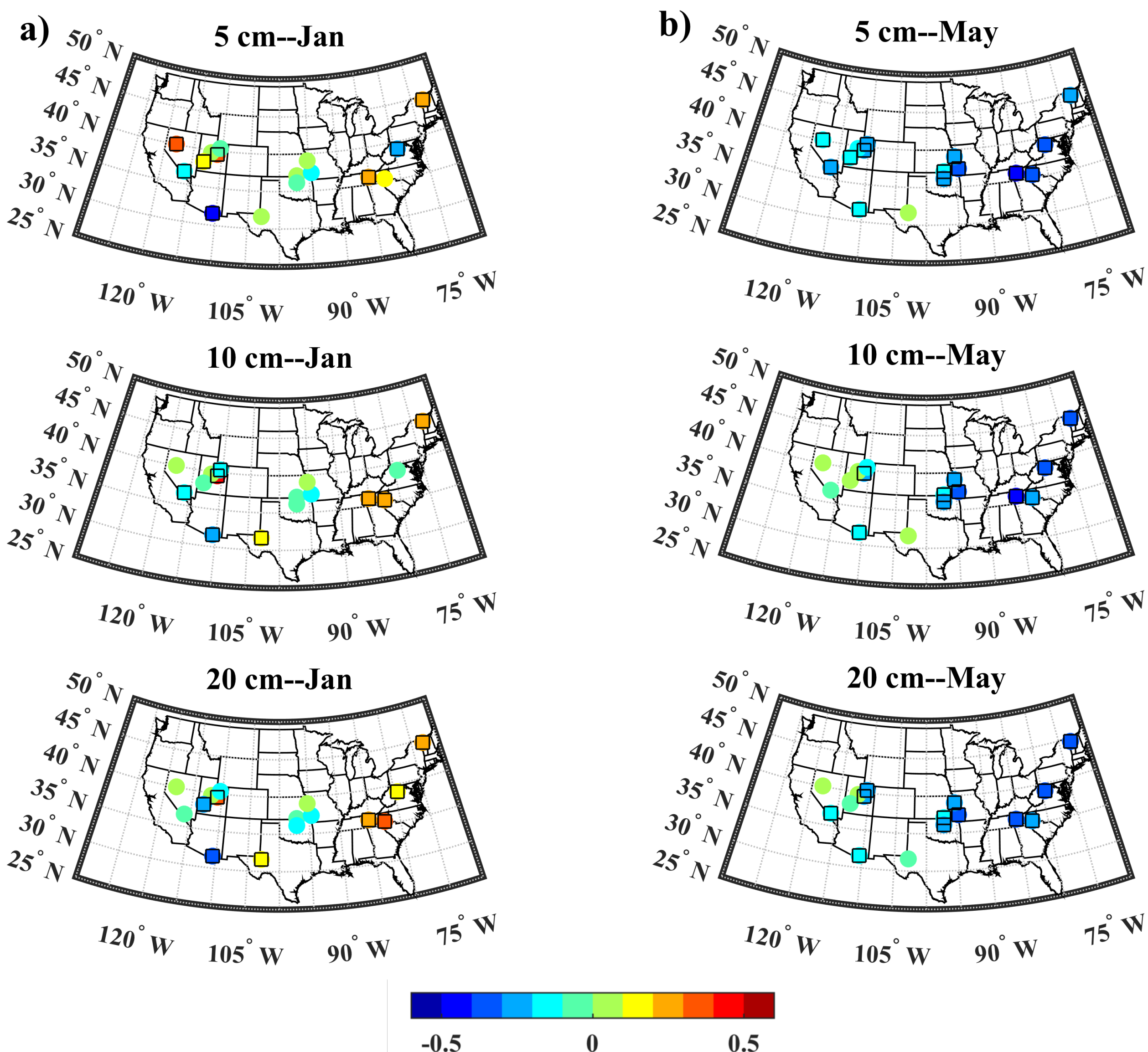
- The meteorological observations, soil moisture data, and soundings from surface Mesonet, Climate Reference Network (CRN), Soil Climate Analysis Network (SCAN) network, and University of Wyoming sounding databases
  - **The correlation coefficient (R)**
  - **Information flow analysis (Liang, 2014 and 2015)**



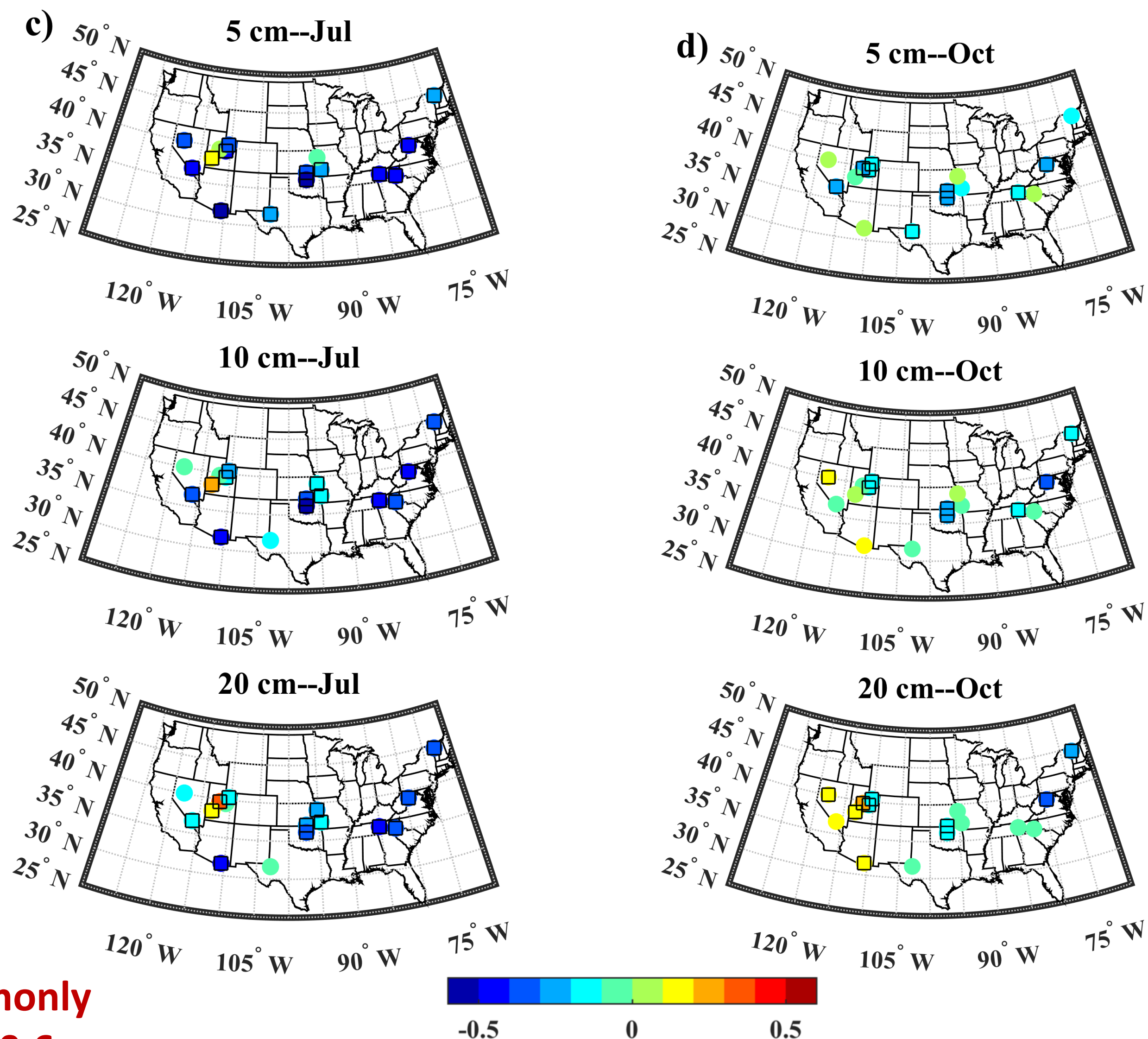
16 soil moisture, 16 meteorological stations, 2 sounding stations (2008-2016)

KPUC, KU14, KMLG, and K74V: **mountain area with shrubland and grassland**.
KWLD, KSWO, KJLN, and KLWC: **plain area with grassland**.
KINK, KFHU, KDRA and KLOL: **desert area with shrubland**.
KW99, KAVL, KCSV and KMVL: **mountain area with forest**.
2 sounding stations: KSLC (Intermountain West) and KOUN (Great Plain)

Correlations between soil moisture and 2-m temperature (January and May)

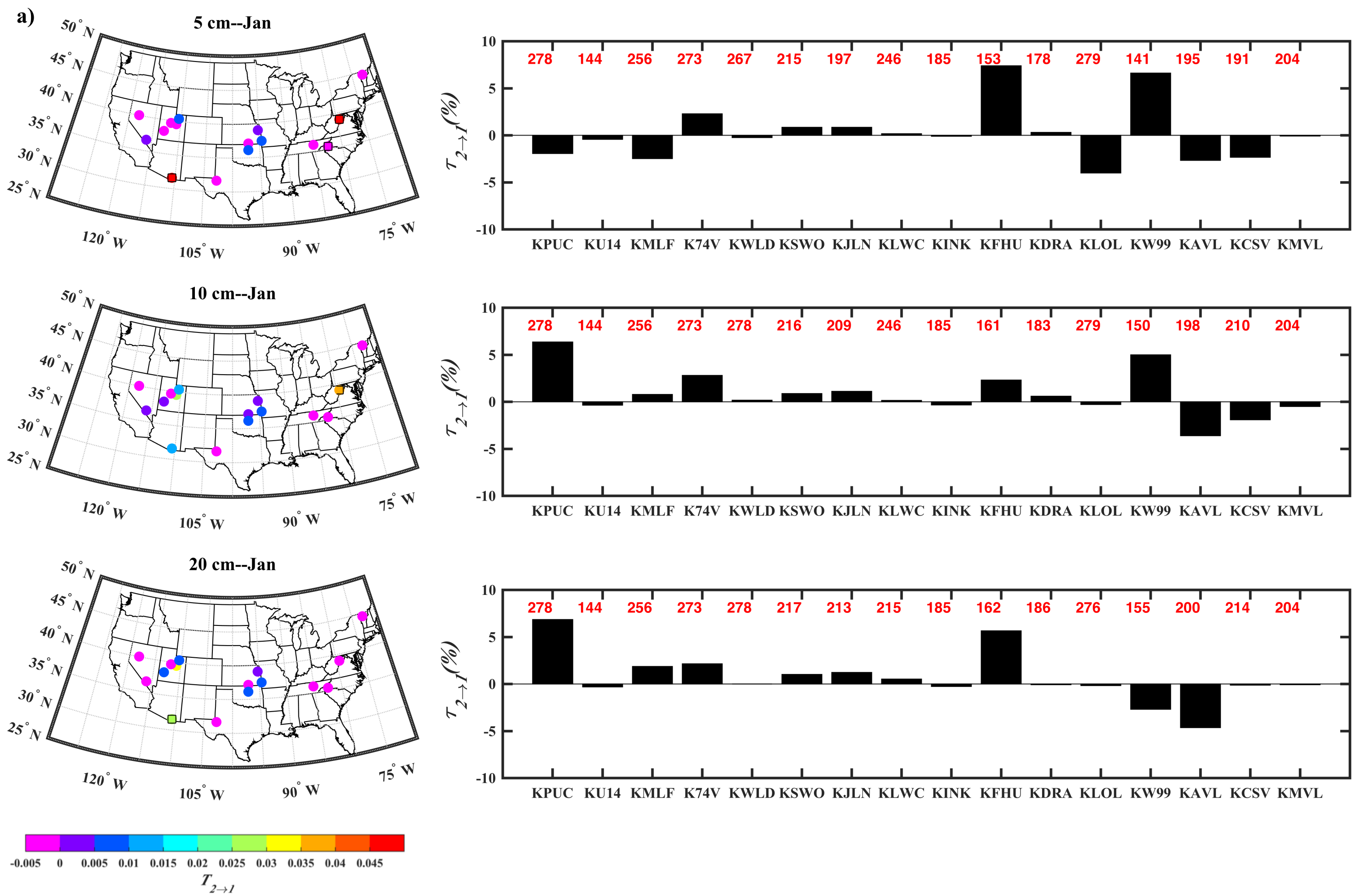


Correlations between soil moisture and 2-m temperature (July and October)

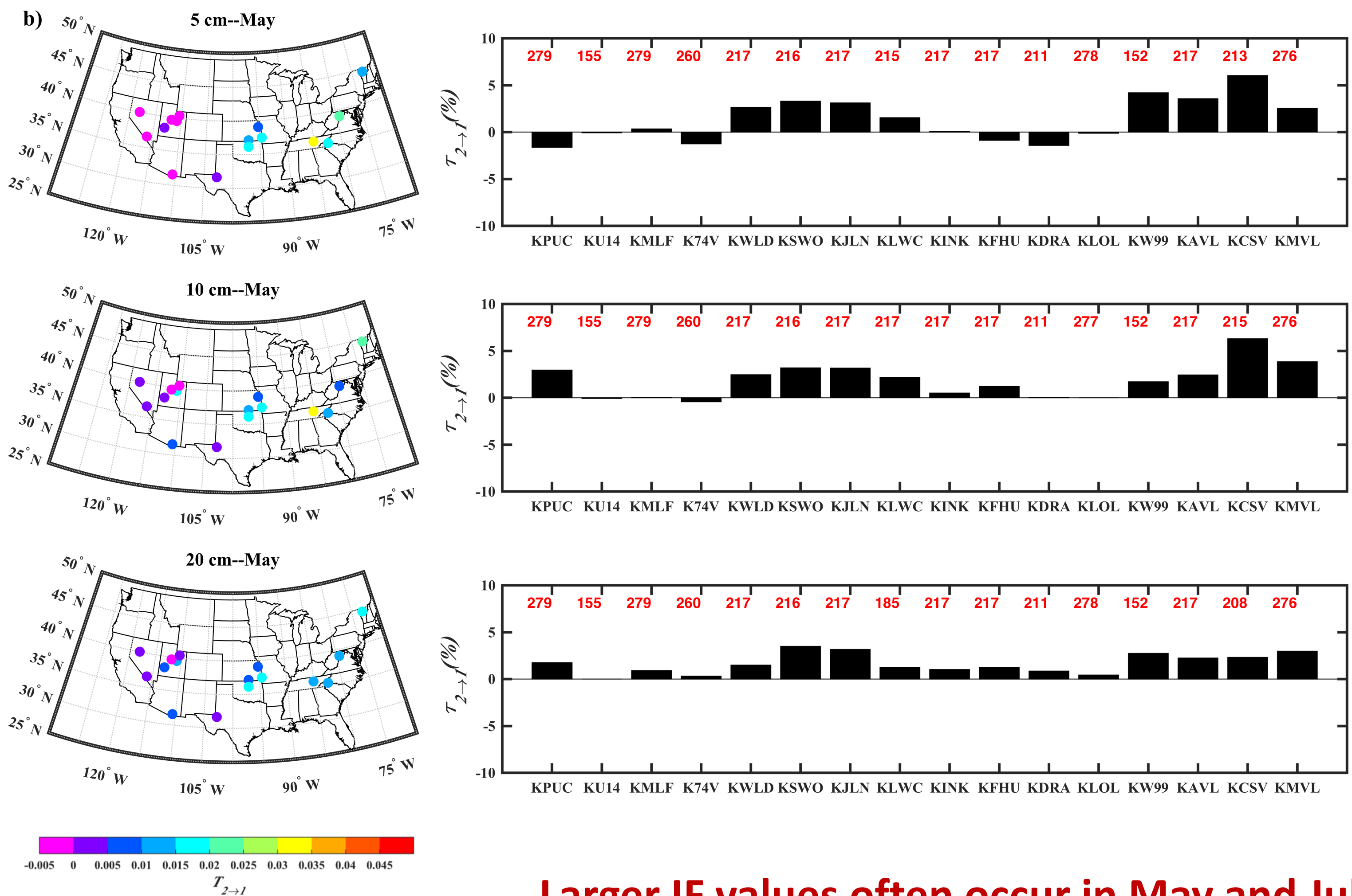


R is commonly less than 0.6

The information flows from soil moisture to 2-m temperature (January)



The information flows (IF) from soil moisture to 2-m temperature (May)



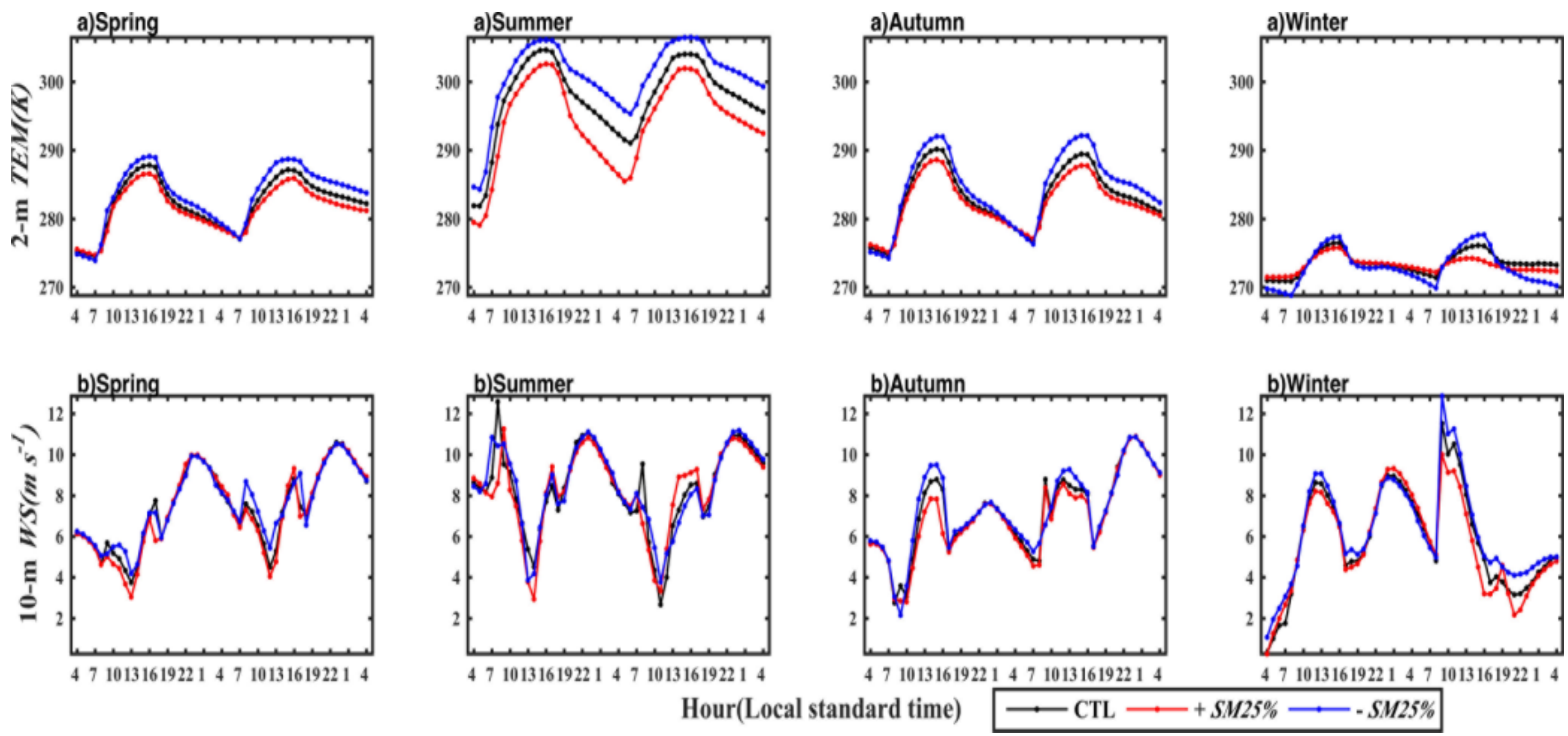
Larger IF values often occur in May and July

Understanding covariances between soil and atmospheric states

A single column model study (Student J. Liu)

- WRF single column model; WRF Version 3.8.1
- RRTM longwave radiation/ Dudhia shortwave radiation/ **Noah Land Surface model** / YSU PBL / WSM-6 microphysics

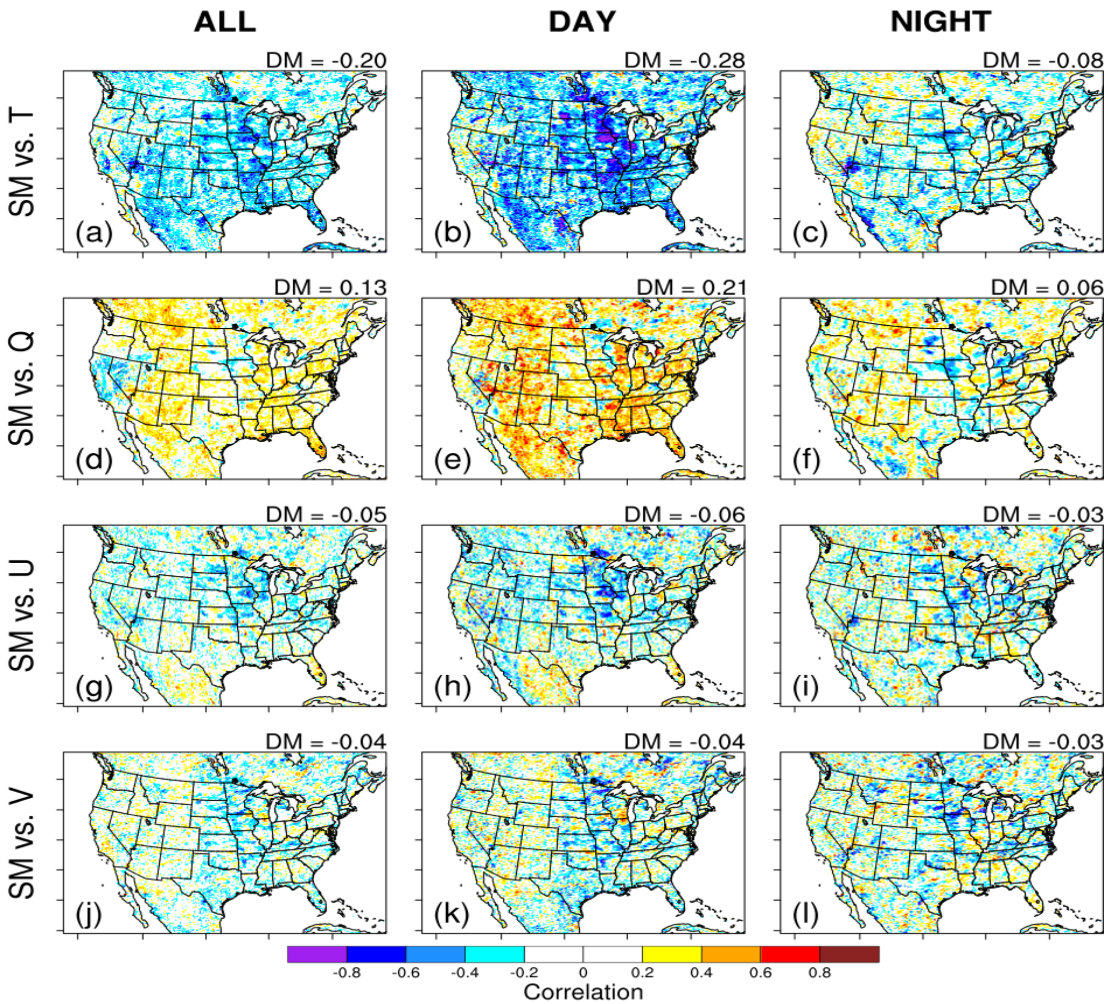
Sensitivity of near-surface variable forecasts to the changes in soil moisture and land use



Understanding covariances between soil and atmospheric states

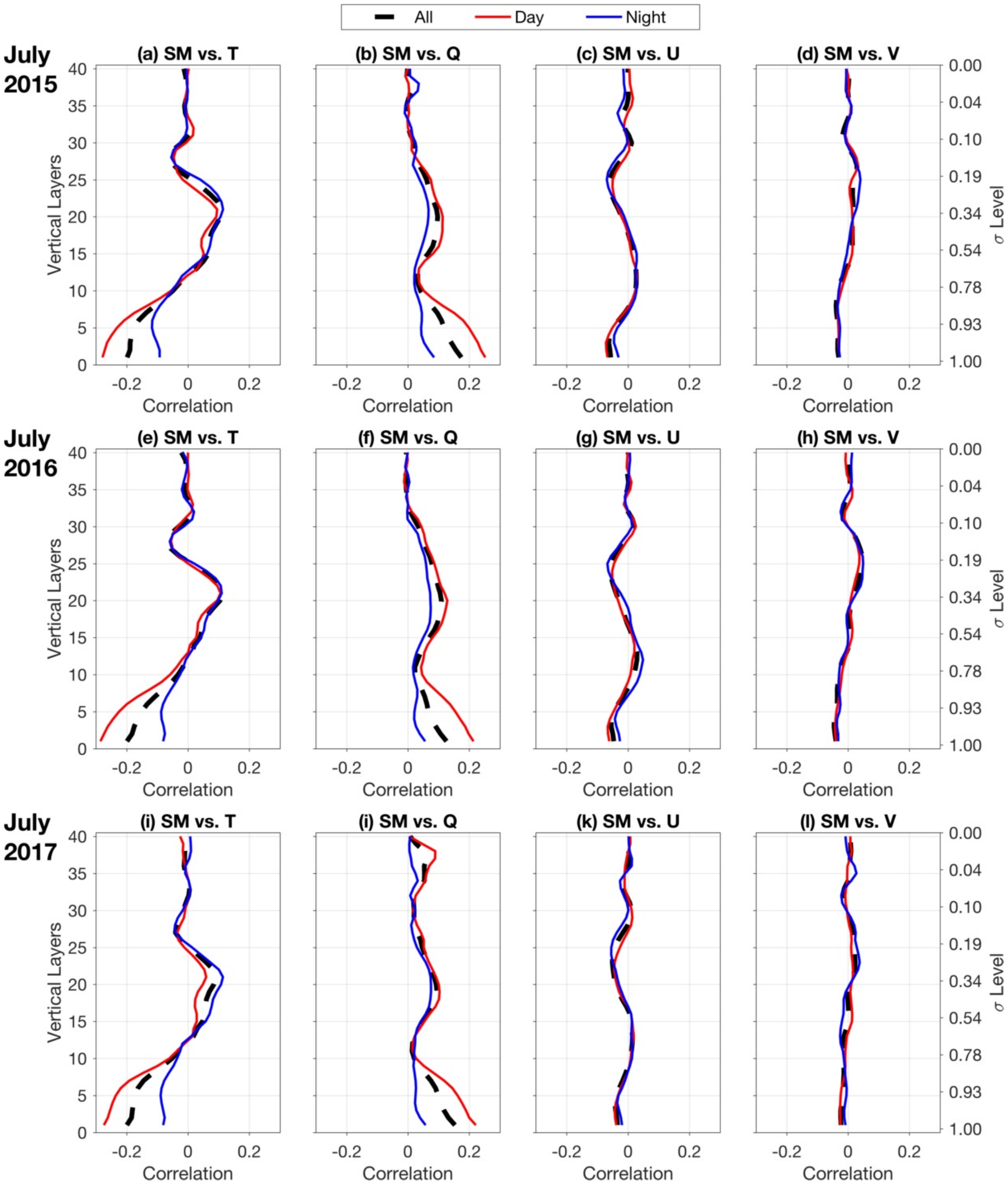
A strongly coupled land-atmospheric system (WRF-Noah)

L.-F. Lin and Z. Pu, JAMC 2018



"NMC-method"

The error correlations between top-layer soil moisture (SM) and bottom-layer atmospheric T, Q, U, and V in July 2016.



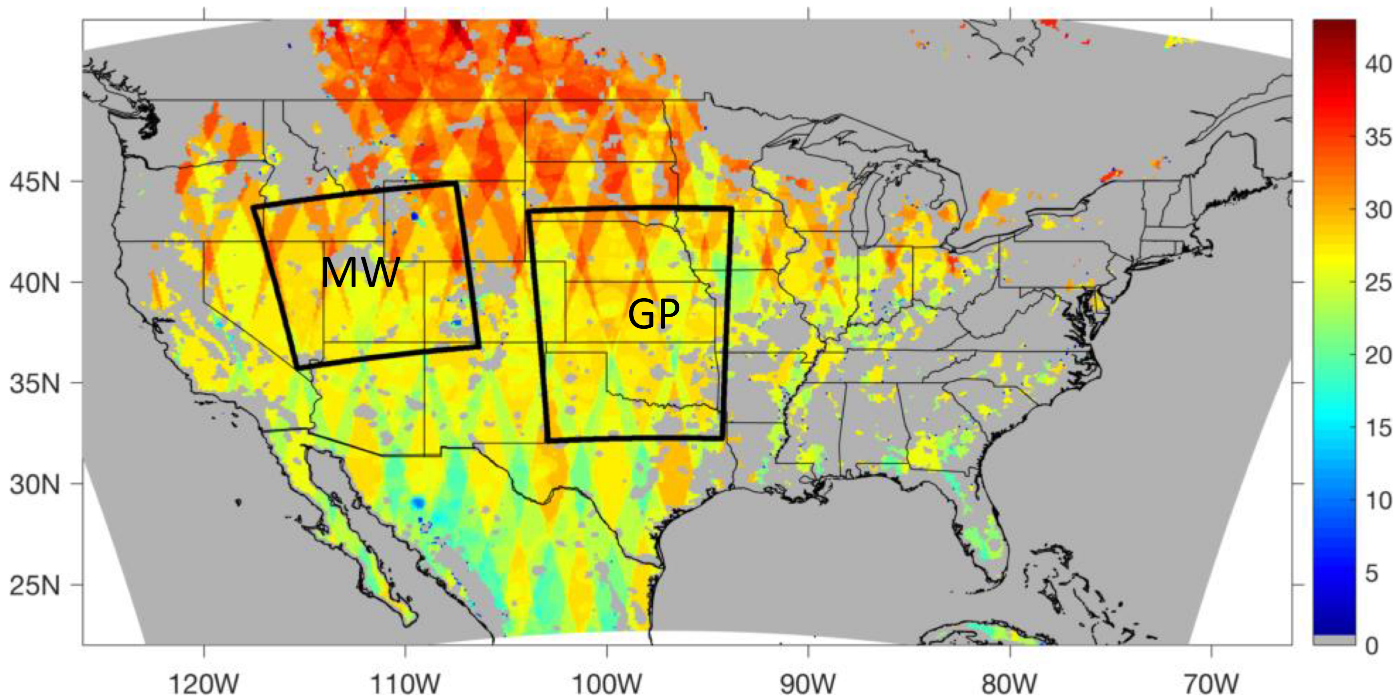
The domain mean error correlation between the top 10-cm WRF-Noah soil moisture (SM) and atmospheric states including potential temperature (T), specific humidity (Q), zonal wind (U), and meridional wind (V) in July from 2015 to 2017.

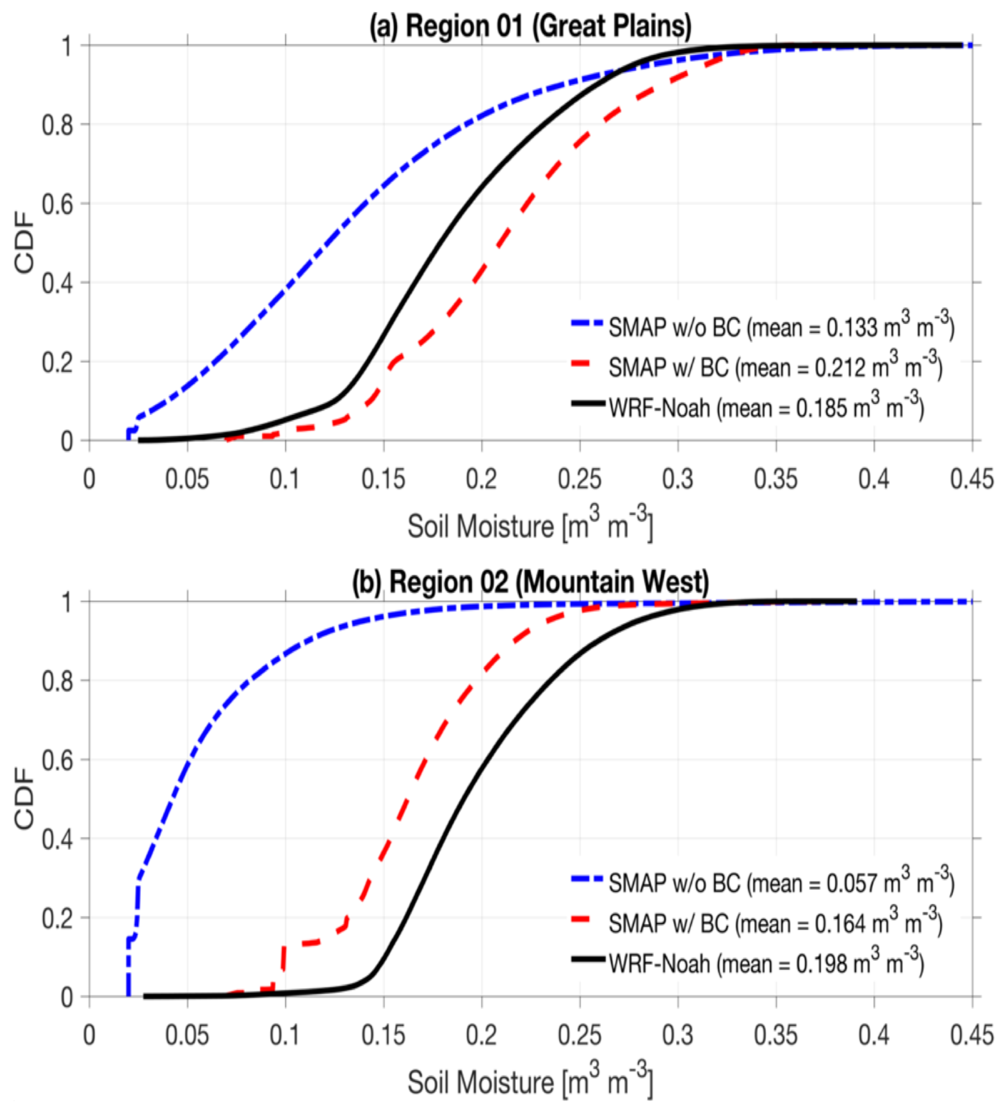
Examining the influence of strong coupling on soil moisture data assimilation with SMAP satellite data: WRF-Noah

L.-F. Lin and Z. Pu, 2018 (preparation)

- Using Version 01 NASA SMAP 9-km enhancement soil moisture with quality control (removing data over surface types of vegetation, urban, water, and snow).

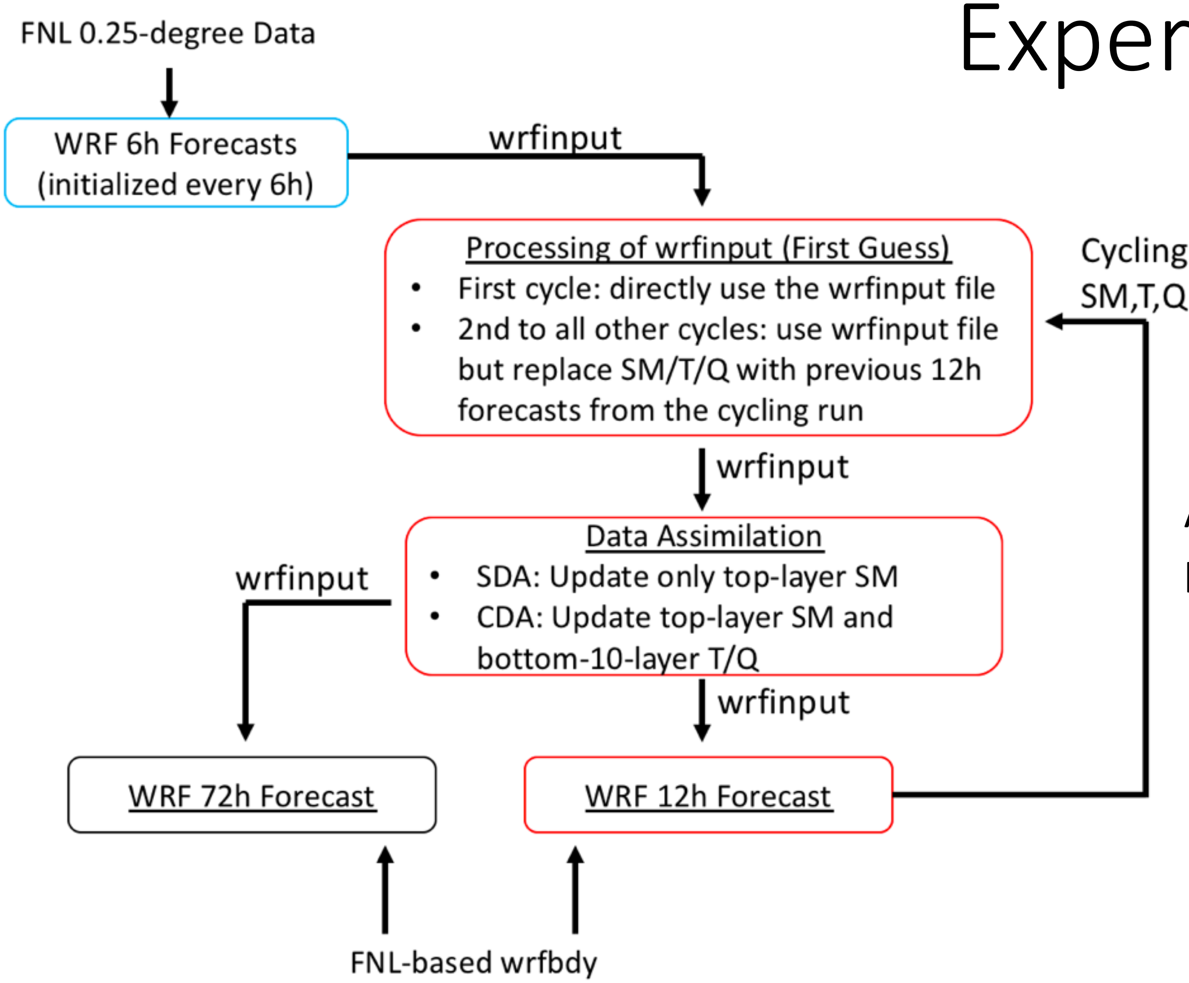
The sample of both descending and ascending data from SMAP in July 2016





- **The soil moisture from Noah and SMAP SM before and after rescaling in July 2016 over the regions of interest**
- **Cumulative distribution function (CDF) matching**

Experiment Design



All the experiments are performed from 1-28 July 2016

- OPL: no any data assimilation
- SDA: update only top-layer SM using non-bias-corrected SMAP SM
- CDA: update SM and T/Q using non-bias-corrected SMAP SM
- SDA_SMBC: same as SDA, except using bias-corrected SMAP SM
- CDA_SMBC: same as CDA, except using bias-corrected SMAP SM

Evaluation Method and Reference Datasets

- Reference datasets:
  - SM: SCAN and CRN gauges
  - T/Q: NCEP FNL 0.25-degree Analysis

- Evaluation Method:

$$\text{Bias} = \frac{1}{N}\sum_{i=1}^{N}(M_i - O_i)$$

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(M_i - O_i)^2}$$

$$\rho = \frac{\sum_{i=1}^{N}(M_i - \overline{M})(O_i - \overline{O})}{\sqrt{\sum_{i=1}^{N}(M_i - \overline{M})^2}\sqrt{\sum_{i=1}^{N}(O_i - \overline{O})^2}},$$

RI (Relative Improvement)

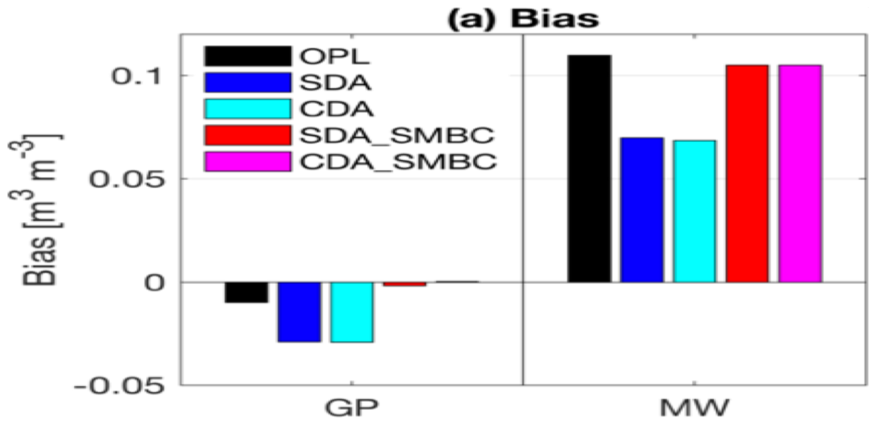
$$\text{RI}_{\text{Bias}} = \left(1 - \left|\frac{\text{Bias}_{\text{DA}}}{\text{Bias}_{\text{OL}}}\right|\right)\times 100\%$$

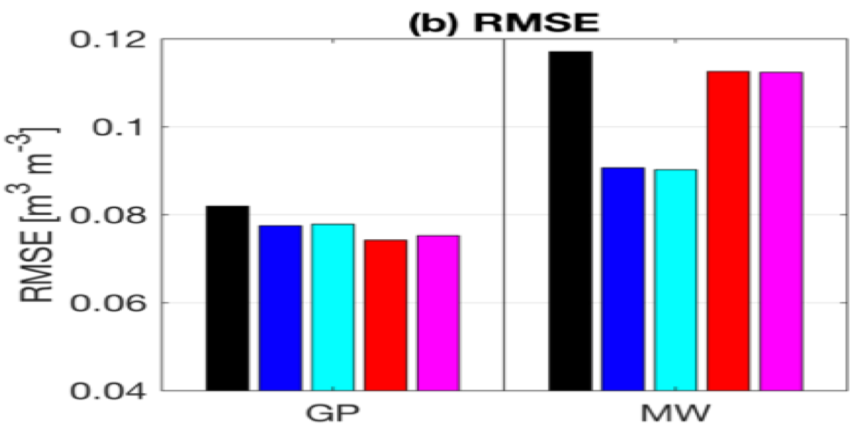
$$\text{RI}_{\text{RMSE}} = \frac{\text{RMSE}_{\text{OL}} - \text{RMSE}_{\text{DA}}}{\text{RMSE}_{\text{OL}}}\times 100\%$$

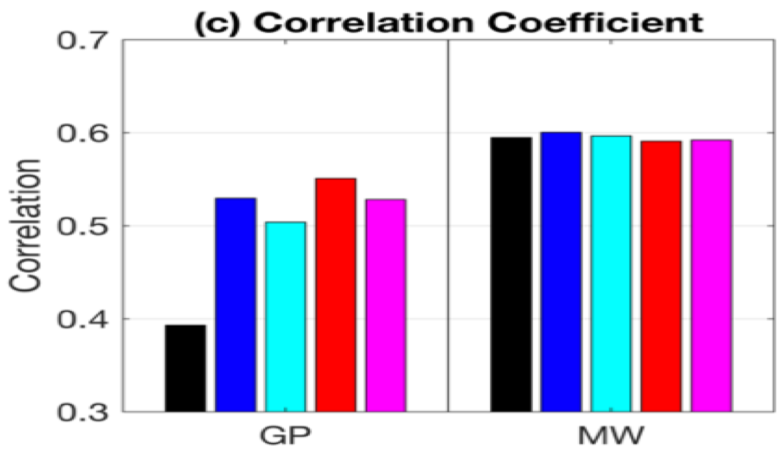
$$\text{RI}_{\rho} = \frac{\rho_{\text{DA}} - \rho_{\text{OL}}}{1 - \rho_{\text{OL}}}\times 100\%$$

Top 10-cm SM Evaluation

Averaged bias, RMSE, and correlation over the regions of interest.

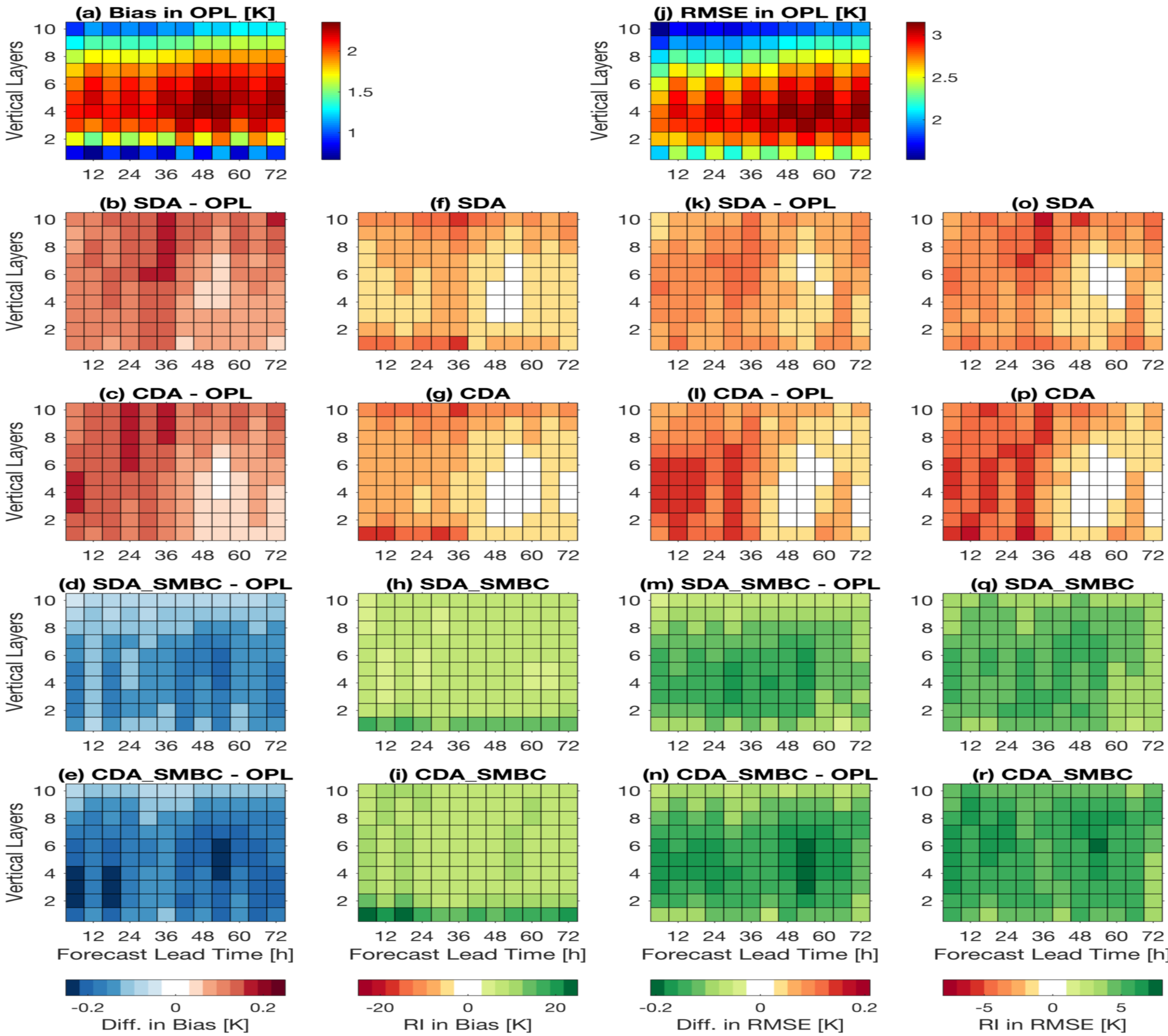






The relative improvement in terms of RMSE and correlation is reported in the table. A positive RI value means that DA improves the model skill.

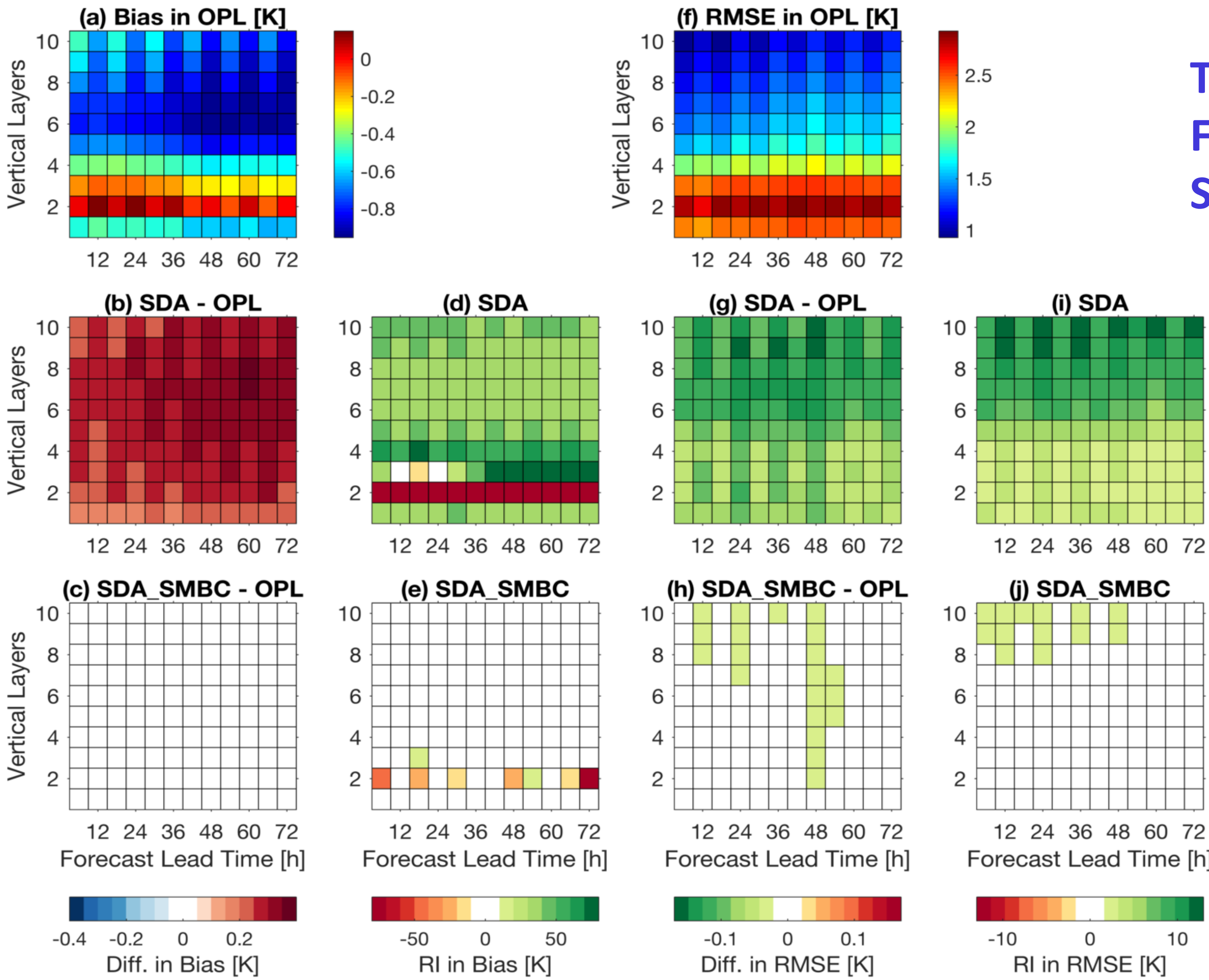
	GP			**MW**	
	RMSE RI (%)	CORR RI (%)		RMSE RI (%)	CORR RI (%)
SDA	5	22		23	1
CDA	5	18		23	0
SDA_SMBC	9	25		4	-1
CDA_SMBC	8	22		4	-1



T Profile Forecast Skill (GP)

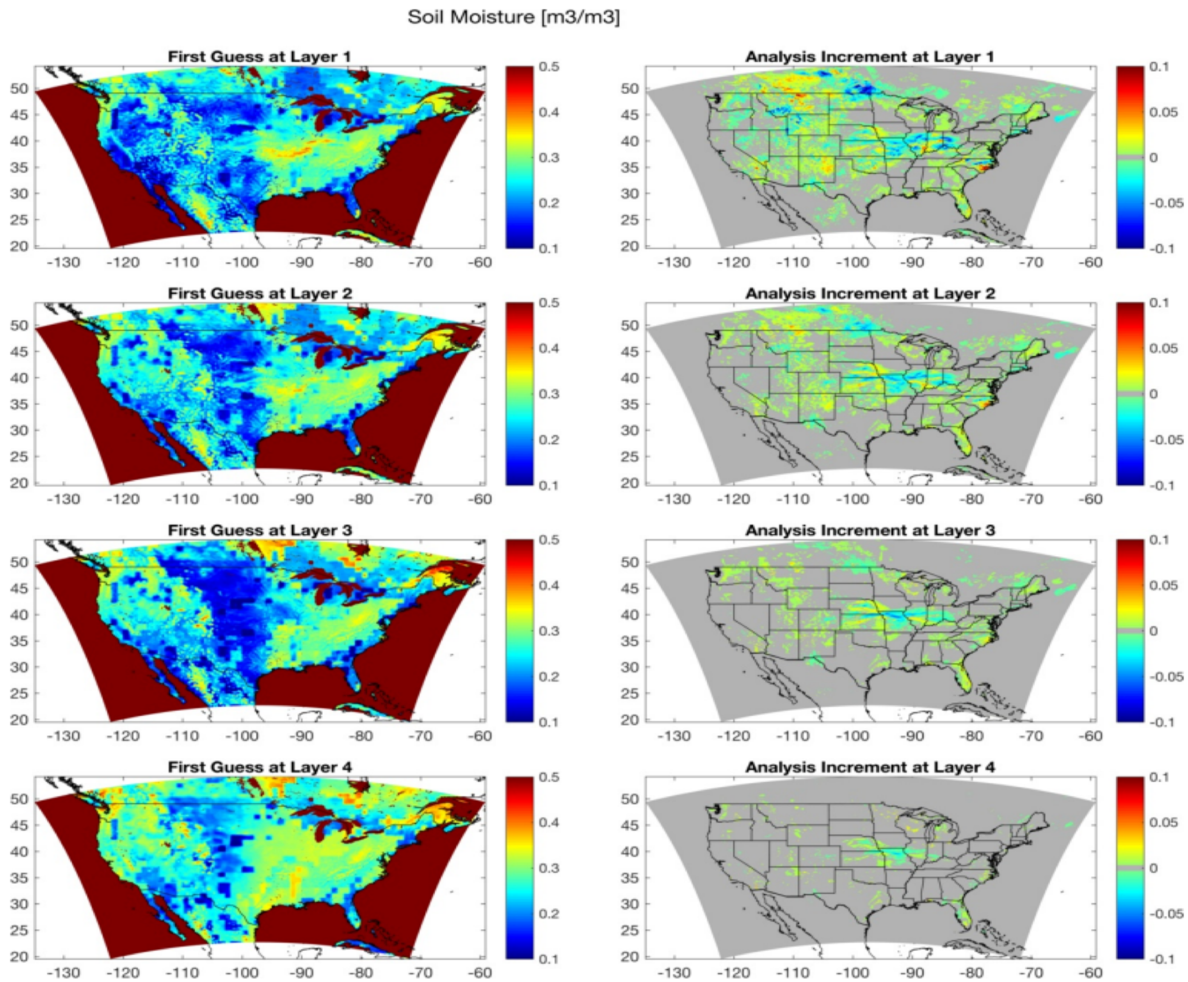
The domain mean metrics (bias and RMSE) over the Great Plains during 11-28 July 2016.

T Profile Forecast Skill (MW)



Ongoing development I: Strong coupling within the GSI framework (Postdoc. Dr. L.-F. Lin)

00 UTC 4 July 2016 -- Soil moisture and analysis increment



To implement the state of soil moisture into GSI EnKF, so that assimilation of conventional data can have impacts on the soil moisture states.

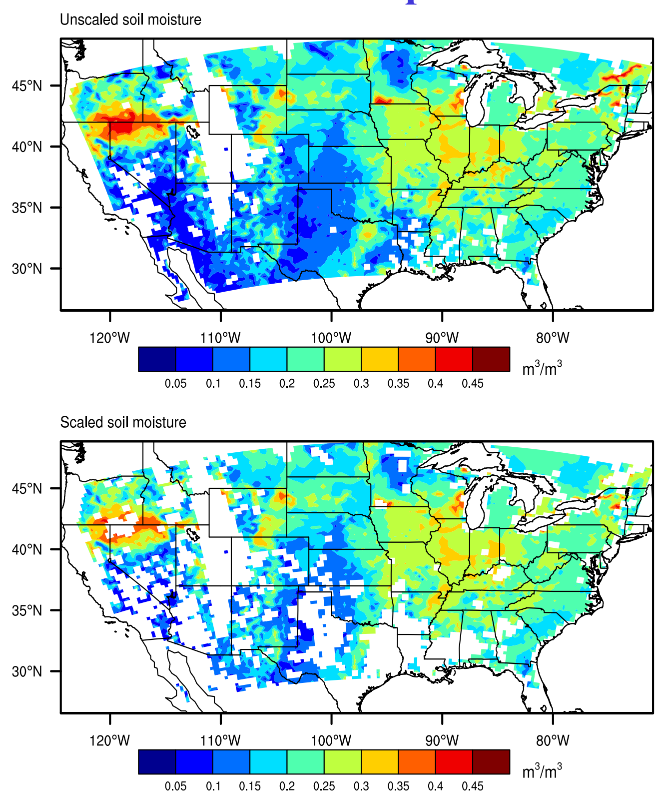
On-going development II: NGGPS (NCEP FV3) coupling with NASA LIS

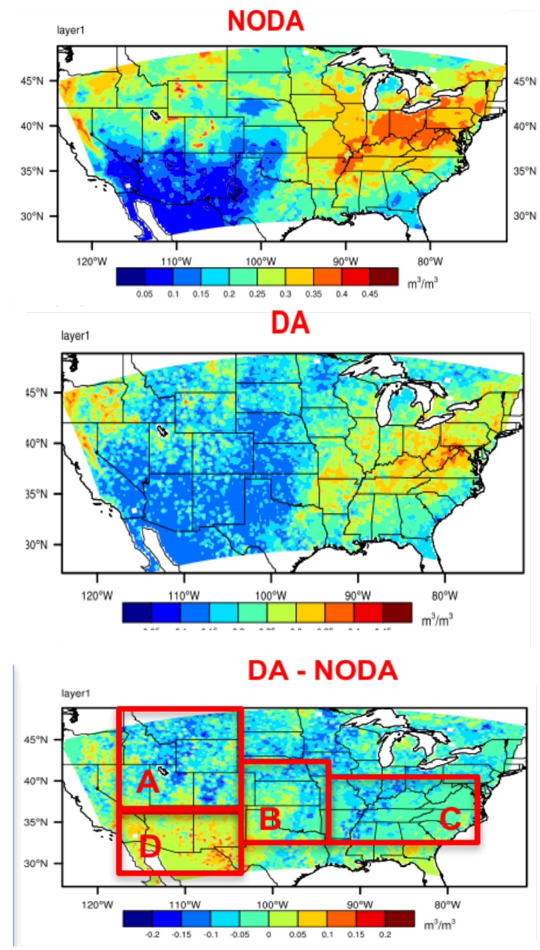
- **Brought up NASA Land Information System (LIS)**

NOAA SMOPS data (5cm)
00 UTC 18 April 2011

Before CDF matching and QC

After CDF matching and QC





Noah top soil layer

After 1-mo cycled DA

- **Attended EMC/NCEP FV3 training course (June 2018)**
- **Plan to work on FV3-LIS coupling**

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